



REVOLUTION

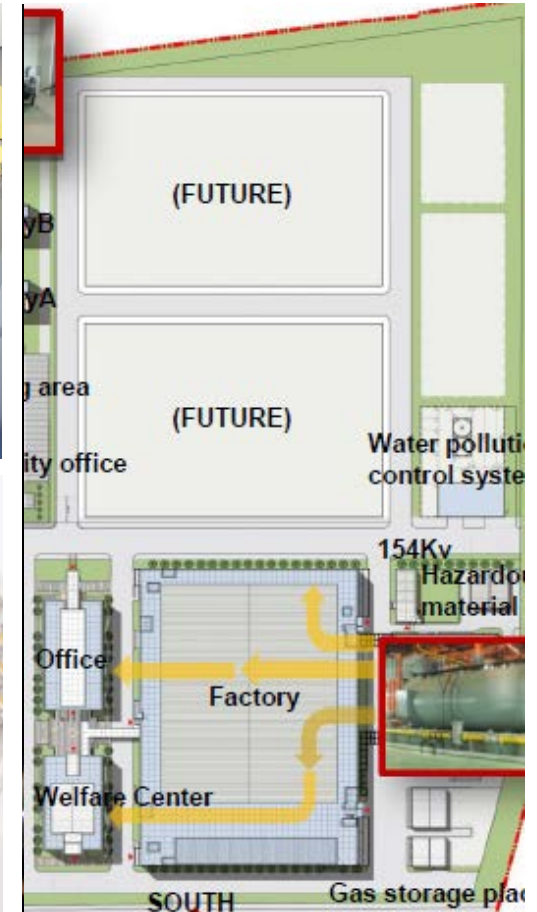
Developing Standards for LED Manufacturing

DOE SSL Manufacturing Workshop

June 13, 2012

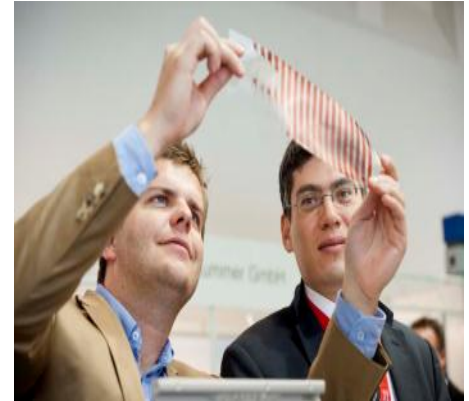
Agenda

- LED Wafer Manufacturing Today
 - Capacity and Equipment Spending by Region
- LED Standards
 - Wafer geometries
 - Factory automation
 - Wafer defects and impurities
 - Manufacturing safety
- Public Policy



SEMI: The Global Association

- Global Association
 - ~2,000 member companies
- LED Events
 - US, Taiwan, Japan, Korea, China, India
- Standards
- Advocacy
- Market Research
- EHS
- Semiconductor, LED, FPD, MEMS, PV, plastic electronics, emerging markets



SEMI LED Advisory Committees

North American and Europe

China

India

Korea

Taiwan

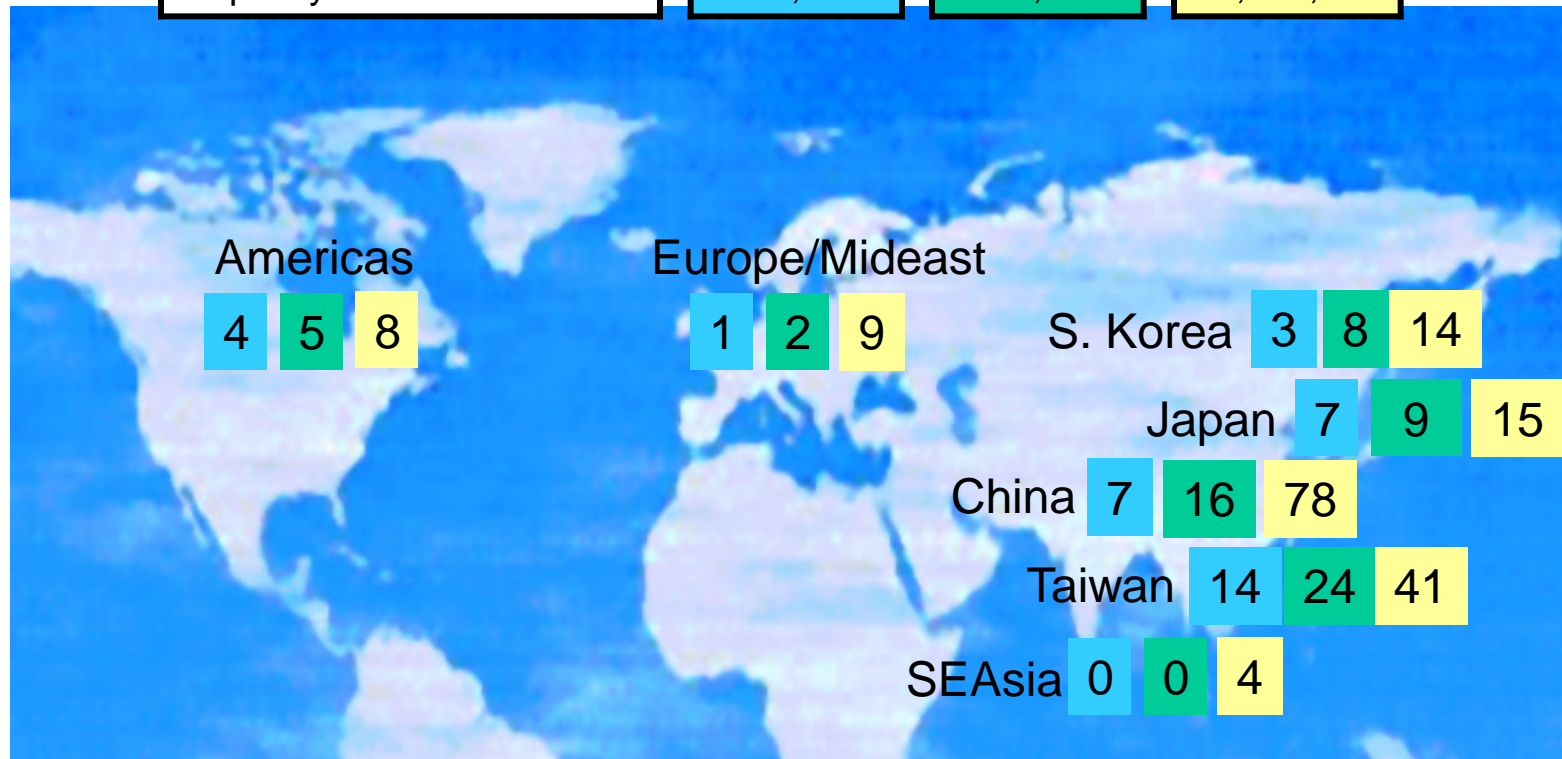
Participating Companies (partial list)



LED Dedicated Fabs

Changing LED Landscape

Year (begin operation)	2001	2006	2012 (est)
Total count of LED fabs*	36	64	169
Capacity in 4-inch EQs w/m	127,124	376,400	~2,030,000



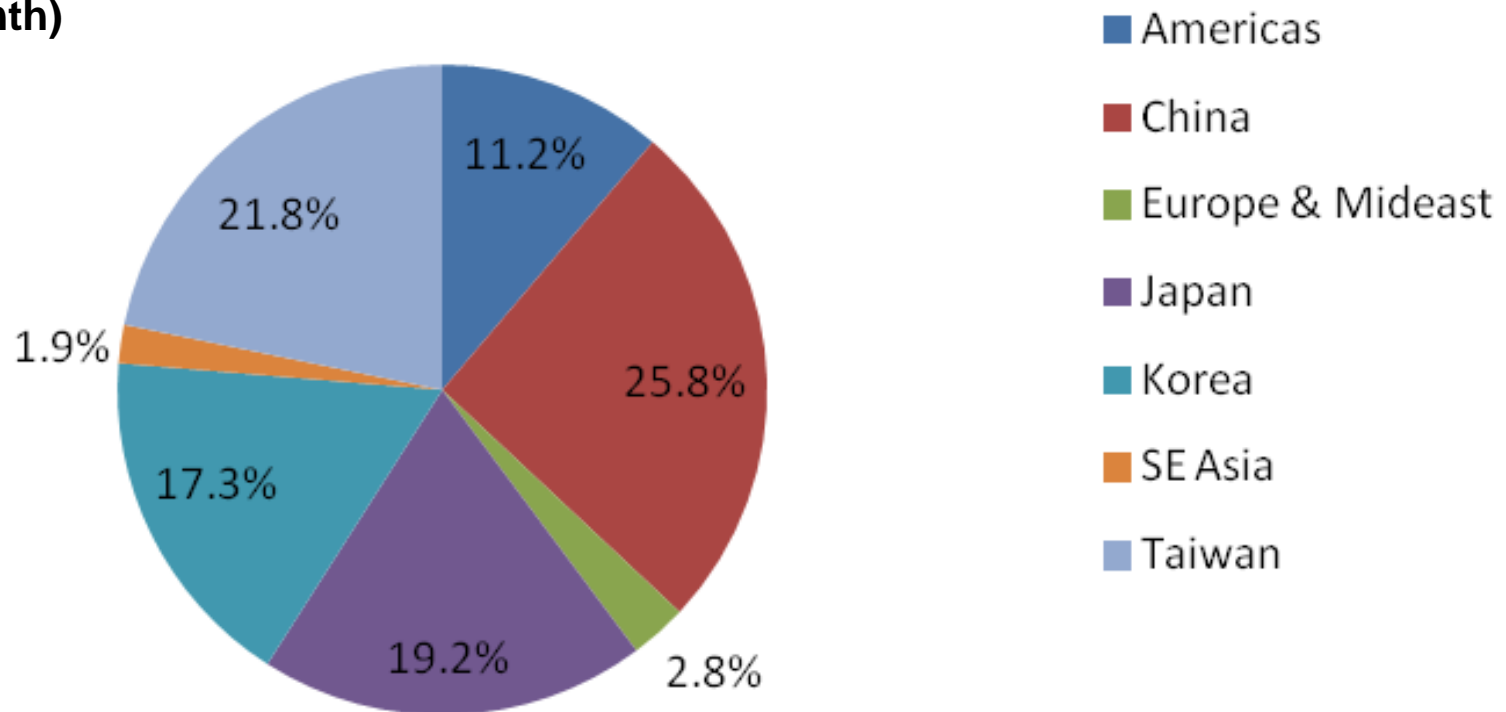
*Fab number includes both LED epitaxy and chip facilities.

Source: SEMI Opto/LED Fab Forecast, April 2012

LED Fab Capacity by Region, 2012

Worldwide LED Epitaxy capacity to reach 2.03 M in 2012 (4" equivalent per month)

2012

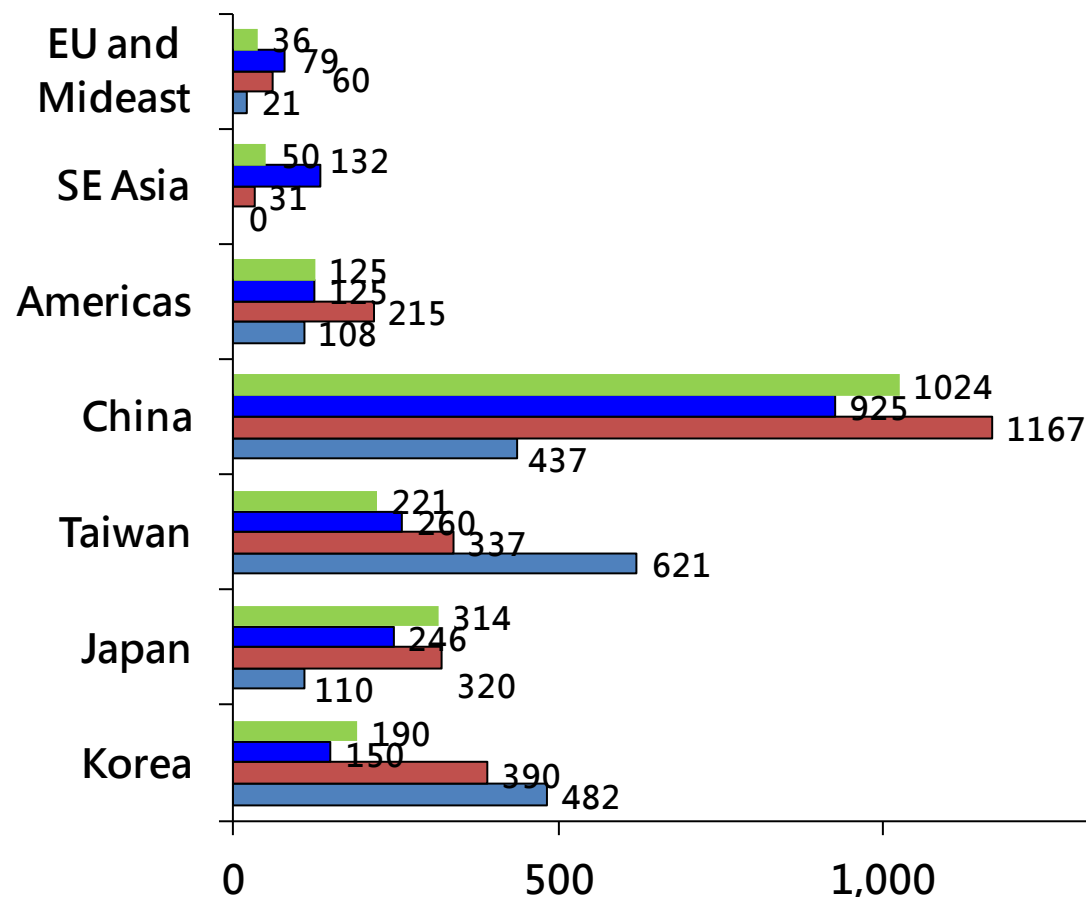


Source: SEMI Opto/LED Fab Forecast , April 2012



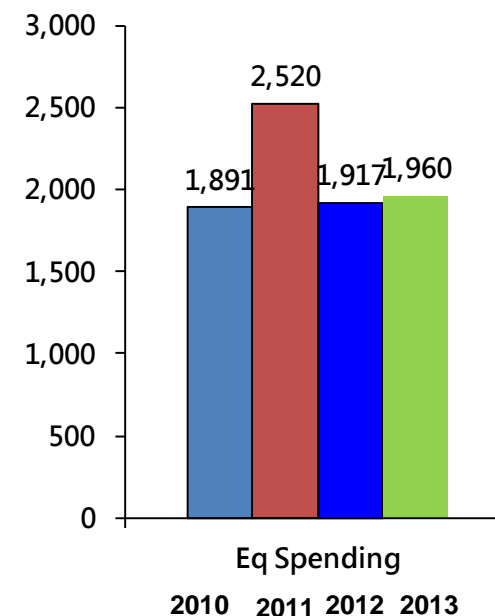
LED Fab Equipment Spending

In \$US Million



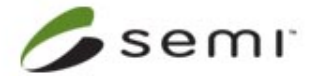
2013 2012 2011 2010

In \$US Million



Source: SEMI Opto/LED Fab Forecast, April 2012

SEMI LED Standards Organization Chart



North America HB-LED Committee

Iain Black (Philips Lumileds)
Bill Quinn (Veeco)
Chris Moore (Semilab)
David Reid (Silian)

HB-LED Wafer TF

Julie Chao (Silian)
David Joyce (GT Advanced
Technologies)

HB-LED Factory Automation Interface TF

Daniel Babbs (Brooks Automation)
Jeff Felipe (Entegris)

Impurities & Defects in HB-LED Sapphire Wafers TF

Luke Glinski (GT Advanced
Technologies)

HB-LED Assembly TF

Paul Reid (Kulicke & Soffa)

Taiwan EH&S Committee

HB-LED Safety Task Force

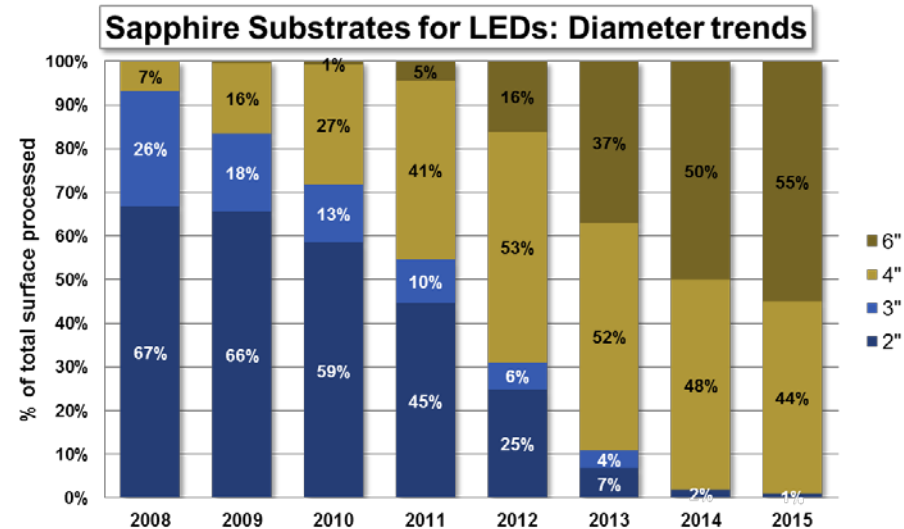
Taiwan

Eric Lin (Epistar)



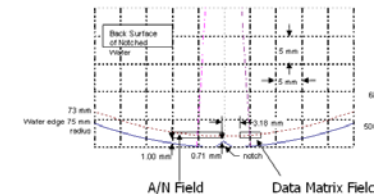
HB-LED Wafer Task Force

- Charter: Define physical geometry of wafers used in HB-LED manufacturing starting with 150 mm diameter sapphire wafers
- Critical LED cost contributor
- Enormous advantages to performing process development on standardized wafers
- Critical contingency on automation standards



Source: Yole Development





HB-LED Wafer Task Force Timeline

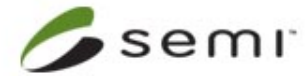


- **July 2011-** New Standard Initiative Approved
 - Doc. #5265: Specification for 150 mm Diameter Sapphire Wafers for HB-LED Applications
- Standards meetings held in US (3), Europe, and Taiwan, Japan
 - Information meetings in China, Korea
- HB-LED Sapphire Wafer Specifications
- **January 2012-** Proposed Wafer Standard goes to ballot
 - Feedback received for ballot 5265 suggested several opportunities for improvement
- Ballot 5265 will be reworked by the TF and will incorporate specifications for 100 mm sapphire wafers
- **May 30, 2012-** Ballot 5265A resubmitted for Cycle 4 voting period (May 30 – June 29)

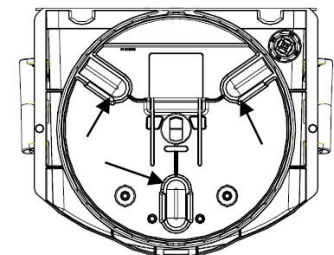
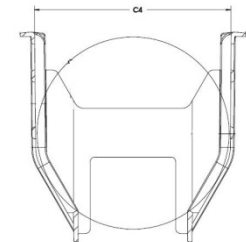
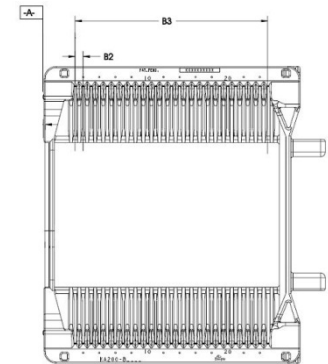


Factory Automation Interfaces

Hardware Working Group



- Charter:
 - Define physical interfaces of substrate carriers used in HB-LED manufacturing
 - Define physical interfaces of process and metrology tools and of wafer / substrate carriers used in HB-LED manufacturing
- Scope:
 - This effort will require some initial discussions around a common vision for an HB-LED factory to which these standards shall apply
 - Start with 150 mm diameter wafers:
 - Cassettes
 - Shipping carriers
 - from wafer supplier to epi processor, and
 - from epi processor to front-end HB-LED device fab
 - Future
 - Automation carriers
 - Process carriers



Kinematic Coupling



Factory Automation Interfaces



Hardware Working Group-STATUS

- Equipment Automation TF – Hardware WG
 - 150 mm Open Cassette Specification
 - Ballot proposal will specify dimensional requirements for both metal and plastic type cassettes; using SEMI E1 as a starting point
 - Moving forward with 16-capacity proposal
 - Ballot 5420 (*New Standard: Specification for Cassettes for 150mm Sapphire wafers used in HB-LED manufacturing*) will be submitted for the Cycle 4 voting period
 - 150 mm Load Port Interface Specification
 - Completion of draft ballot proposal by Fall 2012
 - Ballot submission in Q1 2013



Factory Automation Interfaces

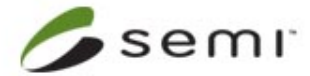
Software Working Group-STATUS



- Equipment Automation TF – Software WG
 - Agreed Plan for Ballot Draft Development of Software interfaces
 - Define boundary conditions for reviewing standards & reporting of required changes
 - Define Phases for reviewing standards
 - Phase 1: Basic communication standards
 - Phase 2: Extended functionalities on SECS II GEM
 - Phase 3: Interface A communication standards
 - Develop draft ballot(s) [Rev A] including Phase 1&2 until Oct 2012
 - Start of Phase 3 after Release of 1st standards version in 2013



Sapphire Impurities and Defects Task Force

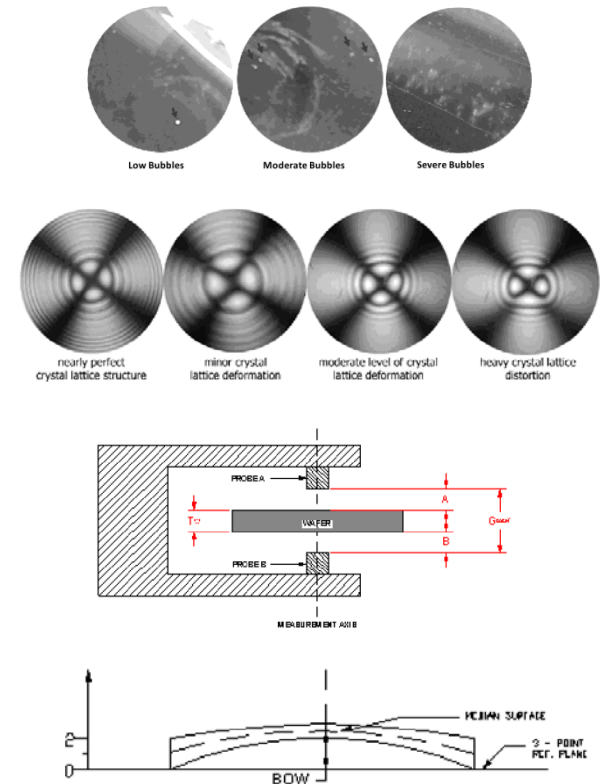


- **Charter:** Investigate the allowable impurities and defects in HB-LED sapphire wafers
- **Scope:** Define and/or measure critical impurities and defects in sapphire wafers and the metrology intended to measure them.
- **Objective:** Create standards related to these impurities and defects for use by HB-LED sapphire wafer makers and producers of related devices.
- Topics to be considered may include, but are not limited to:
 - Bulk Crystal Defects
 - Bulk Crystal Impurities
 - Surface Defects
 - Surface Impurities



Sapphire Impurities and Defects

- Lineages (Low Angle Grain Boundary)
- Bubbles
- Lattice Distortion
- Twins Inclusions TTV – Total Thickness Variation
- Bow
- Warp
- EPD Count



Known Metrology and Tests

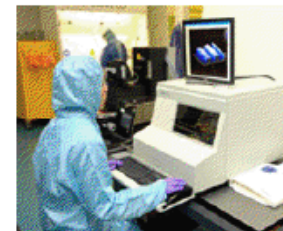
- OHT Polarized Light Inspection (Optical Homogeneity Technique)
- High Intensity Light Inspection
- Polarized Light Microscopy
- X-Ray
- GDMS (Glow Discharge Mass Spectroscopy)
- Surface Profilometers
- Laser Interferometry
- EPD “Etch Pit Density”
- Automated Laser Defect Inspection
- Atomic Force Microscopy
- Acoustic Microscopy



KLA Tencor Candela 6250



PANalytical X'Pert



KLA Tencor P-Series



Dimension, Bruker



Sigmatech Ultra -Map 300



Chapman MPT1000



Sapphire Impurities and Defects Task Force

- Status
 - Reviewed proposed survey document which will identify:
 - sapphire wafer defects that are relevant or important to HB-LED manufacturing
 - inspection techniques can be applied to identify, measure or prevent the identified defect list



Taiwan Safety Task Force

- Charter:
 - The objective is to develop EHS (Environmental health and safety) technical standard specifications and guidelines related to LED (light emitting diodes) manufacturing
- Scope:
 - The activities of the task force will result in the development of an EHS industry standard which equipment suppliers, raw material suppliers, module makers and other involved parties can find conformity.
- Initial work will focus on:
 - Surveying current LED equipment was covered by SEMI S2 or not.
 - Developing EHS guidelines for manufacturing equipment of LED industry.
- Future works may include:
 - Establishing equipment safety event database
 - Collecting and analyzing the data of safety notice and SEMI reports which were certified by third party
 - Developing SEMI EHS standards for LEDs manufacturing.



US Policy

- **Increase DOE funding** for both R&D and manufacturing infrastructure development of the U.S. LED/SSL industry
- **Establish the R&D tax credit** on a long-term basis to assure LED/SSL manufacturers greater consistency in tax and investment planning
- **Revive the Advanced Energy Manufacturing Tax Credit (MTC)**, and creation of a federal Green Bank to supplement LED and other green energy projects, particularly for manufacturing.
- Work with foreign counterparts and the WTO to develop a strong, effective and enforceable rules-based international trading system that promotes free and open trade.
- Support reasonable export control work that applies to LED/SSL in the movement to decontrol MOCVD tools.



Thank You

Tom Morrow
SEMI
tmorrow@semi.org

